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ANALYSIS OF SULFUR DIOXIDE EXCESS AT COLBERT STATION 1 ON NOVEMBER 7, 1980

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AIR RESOURCES PROGRAM

TVA/ONR/ARP-81/4

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Air Resources Program

ANALYSIS OF SULFUR DIOXIDE EXCESS AT COLBERT STATION 1 ON NOVEMBER 7, 1980

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March 1981

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II

ANALYSIS OF SULFUR DIOXIDE EXCESS AT COLBERT STATION 1 ON NOVEMBER 7, 1980

SCOPE AND OBJECTIVES

On November 7, 1980, sulfur dioxide (SO_2) levels in excess of the secondary National Ambient Air Quality Standard (NAAQS)[1] were measured at monitoring station 1 near Colbert Steam Plant. SO_2 concentrations exceeding the 3-hour secondary standard of 0.5 ppm (0.557 ppm) were measured for the period 0400-0700 CST on November 7, 1980. This was the only excess of the calendar year and therefore did not constitute a violation of the standard. Colbert Steam Plant was in compliance with the 4.0 $lb/10^6$ Btu SO_2 emission standard at the time the excess occurred.

The purpose of this report is to examine the physical and environmental circumstances associated with the November incident, document these circumstances as completely as practical, and determine the sources in the vicinity of station 1 that were contributors to the incident. Data bases used during this investigation included: meteorological tower data from Colbert Steam Plant, upper air meteorological data from Johnsonville Steam Plant, air quality data from the Colbert Steam Plant monitoring network, National Weather Service (NWS) data, topographic maps, and Colbert operational data. This report presents and evaluates all available data and information related to the November 7, 1980 measurements.

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1. For SO_2, the primary standard (for protection of public health) is 0.14 ppm for a 24-hour average; the secondary standard (for protection of public welfare) is 0.5 ppm for a 3-hour average. These standards are not to be exceeded more than once per year at any one station.

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PHYSICAL AND ENVIRONMENTAL FACTORS

The relevant physical and environmental factors are (1) the Colbert Steam Plant vicinity, (2) emissions from sources with the potential to impact station 1, and (3) meteorological and air quality monitoring data.

COLBERT STEAM PLANT VICINITY

Steam Plant Environment

Colbert Steam Plant is located in northwest Alabama about 18 kilometers (km) west-southwest of Florence, Alabama. It is located in a rural area along the south shore of the Tennessee River, near a river bend as the direction of river flow changes from west to northwest. Terrain is generally flat to slightly hilly, although significantly higher terrain (up to 135 meters (m) above plant grade) exists within three to six km to the southeast, south, and southwest.

Colbert monitoring station 1 is located in a rural area 2.9 km north-northeast of the steam plant at an azimuth of 23°. The station meets SLAMS criteria[2] for siting SO_2 monitors. The site is a level lawn with an unpaved road located 40 m to the east of the station. Within 200 m surrounding the site,[3] there is no heavy or light industry, housing is negligible, and land use is 10 percent forest, 80 percent agriculture, and 10 percent pasture. All tall structures or trees at this site meet minimum distance criteria for SO_2 monitoring.

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2. SLAMS: State and Local Air Monitoring Station siting criteria. These criteria have been established as part of standardized air monitoring guidelines for monitor location, data collection and processing, and instrument calibration.

   40 CFR Part 58. "Ambient Air Quality Surveillance."

3. The area within 200 m is subjectively examined to determine if there are any extremely local sources of interference which might affect the monitor.

Air Quality and Meteorological Monitoring

TVA operates a network of five SO_2 monitors in the vicinity of Colbert Steam Plant (figure 1). At each station, SO_2 is continuously monitored coulometrically with a Philips PW-9700 ambient monitor.

A TVA-operated meteorological tower is located near Colbert Steam Plant. Temperature is measured at three levels (1 m, 10 m, and 110 m); wind speed, wind direction, and wind direction persistence are measured at two levels (10 m and 110 m). In addition, solar radiation, total radiation, rainfall, and atmospheric pressure are measured continuously. All data are summarized hourly.

On November 7, 1980, 3-hour average SO_2 concentrations exceeding the secondary 3-hour ambient air quality standard were recorded at station 1 (2.9 km north-northeast from Colbert Steam Plant) for one period; 0.557 ppm during 0400-0700 CST. This represents an excess, but not a violation, of the secondary standard (one excess per year is permitted). Pertinent SO_2 measurements from the Colbert monitoring station 1 are presented below.

SO_2 MEASUREMENTS DURING 3-HOUR EXCESS AT COLBERT STATION 1

November 7, 1980

Hour Ending (CST)	Peak SO_2 Concentration (ppm)	1-Hour Average SO_2 Concentration (ppm)	
0200	0.100	0.060	
0300	.070	.010	
0400	.340	.010	
0500	.680	.310	) Excess
0600	.910	.750	) (3-Hour Average =
0700	.900	.610	) 0.557 ppm)
0800	.660	.310	
0900	.020	.000	

SO_2 concentrations for all other stations in the Colbert network for November 7, 1980 did not exceed 0.020 ppm hourly average. All pertinent SO_2 data are listed in appendix A.

Relevant meteorological tower data are listed in appendix B. During the incident period, the tower top (110 m) wind direction ranged from 202 to 205°, almost directly towards monitoring station 1. Wind speeds at the 110-m level exceeded 5 m/sec throughout the period.

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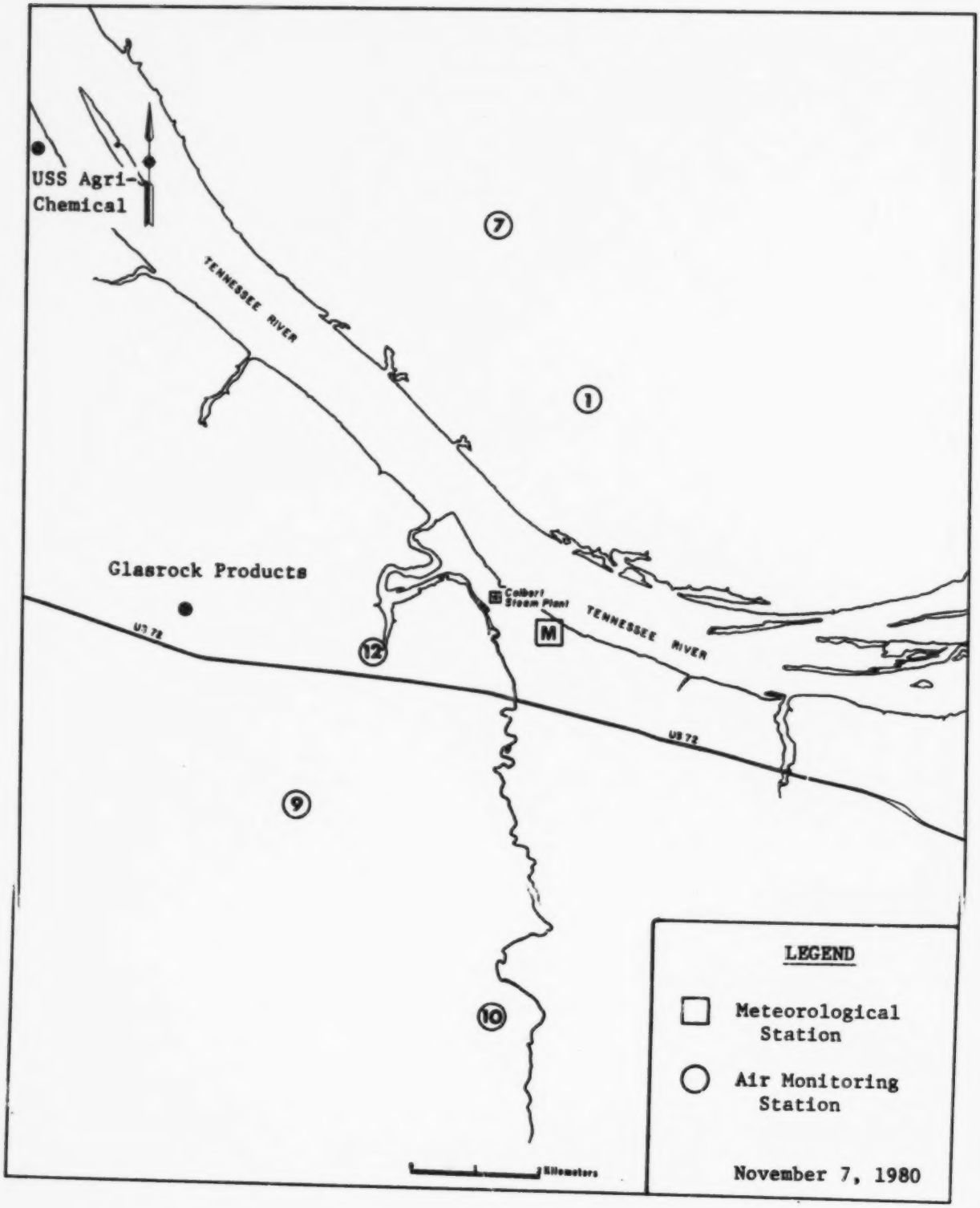

Figure 1. COLBERT STEAM PLANT AIR MONITORING NETWORK

SURVEY OF SO_2 EMISSION SOURCES

Colbert Steam Plant

TVA's Colbert Steam Plant is the largest major source of SO_2 in the vicinity. The steam plant has two 200-MW units and two 223-MW units, each with a 91-m stack; and a single 550-MW unit with a 152-m stack. A single 183-m stack is being constructed to replace the four shorter stacks as part of the Alabama State Implementation Plan (SIP), and is scheduled for completion in April 1983. At capacity, the steam plant emits approximately 5300 g/sec of SO_2, assuming 2.3 percent sulfur coal, or about 3.8 pounds of SO_2 per million Btu--below the 4.0 pound emission standard in the Alabama SIP.

Other Nearby Sources

There are several emission sources near Colbert Steam Plant--USS Agri-Chemicals, Glasrock Products, and local domestic heating (cold weather only). However, these sources are generally too distant with SO_2 emissions too small to significantly influence monitoring station 1.

Distant SO_2 Sources

The metropolitan Quad-Cities area (15-25 kilometers east of Colbert Steam Plant) contains numerous emission sources. These sources are too distant with SO_2 emissions too small to significantly influence monitoring station 1.

METEOROLOGICAL FACTORS

The available meteorological data related to this incident are included in appendix C. They consist of NWS surface weather maps, NWS upper-level (850 mb) charts, TVA meteorological tower data from Colbert Steam Plant, and TVA aircraft/pibal data from Johnsonville Steam Plant, the closest upper air observing station. Basic dispersion parameters related to this incident were derived from these records and charts. Atmospheric processes occurring on the following scales were considered: (1) the scale depicted by the synoptic weather maps; (2) a mesoscale which is affected by surface terrain features that modify wind and thermal field in the free atmosphere; and (3) a microscale which commonly includes 10 to 15 m above the earth's surface. Events at these separate scales both overlap and interact.

A high pressure system was centered over northern Florida and the Gulf of Mexico throughout the period of high SO_2 concentrations. A stationary front extended from North Dakota, through South Dakota and Iowa, along the Illinois/Wisconsin state line, then through lower Michigan

and into Canada. A low pressure center, located in central Iowa at 0000 CST on November 7, 1980, moved along this front to a position in northwest Illinois at 1200 CST. A low pressure trough (line of low pressure) extended from the low pressure center toward the southwest into Texas. The low pressure/stationary front system induced strong and persistent wind flow from the southwest over the Tennessee Valley region.

Upper-air conditions over Colbert Steam Plant were derived from upper-level measurements over Johnsonville Steam Plant (approximately 140 km north of Colbert Steam Plant), which was located in the same basic weather regime as Colbert Steam Plant.

The vertical structure over Colbert Steam Plant was characterized by four features during the period of highest SO_2 concentration: (1) a surface-based isothermal layer extended to about 500 m above the surface and deep enough to prevent penetration by the Colbert plume; (2) the slightly stable lapse rate ($0.8^{\circ}C$/100 m--stability class E) in the 10-110 m layer; (3) steady wind directions from the south-southwest and southwest in the isothermal layer; and (4) moderate to strong wind speeds (8-18 m/sec).

The Colbert plume passed over the Tennessee River (approximately 1 km wide) and toward monitoring station 1. Since water tends to cool slower than land, it is likely that the atmosphere over the river was slightly warmer than the atmosphere over land (the temperature over the river was as much as $2.9^{\circ}C$ warmer based on river station air temperature observations). However, the existing surface-based stable layer was sufficiently strong that it probably was not eliminated over the river; the lapse rate would have been slightly less stable, but would have remained within the same stability class (class E). Therefore, the effects of the river on the vertical temperature profile were probably insufficient to affect the Colbert plume.

Although the terrain around Colbert Steam Plant is generally flat, the steam plant is located on slightly elevated ground. This location and the steam plant structure itself (exclusive of stacks) obstructs the wind flow up to 45 m above river level. Airflow is diverted both over and around terrain features and structures, creating eddies behind terrain/structure obstructions. These eddies, and a downward airflow on the backside of obstructions may lower the effective plume height and modify plume dispersion.

NATURE OF THE EXCESS

There are several forms an excess might take. An excess at one site might represent the maximum of elevated concentrations observed at all or a number of sites in a network. Alternatively, it could be an isolated event which affects one monitor, but not any of the others.

The persistence of high concentrations during an excess must also be considered. The nature of an excess, i.e., the spatial distribution and persistence of high concentrations, is important in identifying sources which might be responsible.

The following observations about the nature of the excess can be made based on a review of network ambient air monitoring data and of the actual strip chart recording during the excess.

1. No other station in the Colbert monitoring network measured any SO_2 above background levels. This indicates an isolated nearby source since a distant source would have impacted several monitors.

2. Elevated SO_2 concentrations at station 1 were restricted to a short time period (0300-0800 CST) and characterized by a jagged "peaks and valleys" type trace, not a flat trace during the high concentration period. This SO_2 concentration pattern is associated with a single large point source.

3. Peak and hourly average SO_2 concentrations followed the same increase/decrease trend during the high concentration period. As hourly averages increased or decreased, so did peaks, although changes were not at the same rate. This indicates a single plume shifted direction as the centerline first moved closer to the station and then moved away.

4. SO_2 concentrations were closely related to wind conditions. Highest concentrations occurred when wind speeds were 5-6 m/sec, hourly average wind direction was 202°, and wind direction persistence was above 90 percent (110-m level). Concentrations dropped significantly when wind conditions were outside these limits. This indicates a persistent impact from a single nearby source.

These observations indicate that monitoring station 1 was probably influenced by a large, isolated, nearby SO_2 emission source. Distant emission (greater than 10 km away) were not a significant factor in the excess.

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DISCUSSION OF EXCESS

In the previous section, topographic, meteorological, and other factors important to determining the cause of the excess were examined. In this section, the specific circumstances related to the excess will be discussed.

PROBABLE EMISSION SOURCE

Colbert Steam Plant is the only SO_2 emission source both large enough and close enough to monitoring station 1 to cause the excess observed. At the time of the excess, units 1-4 were operating near full load and unit 5 was off-line. All other potential sources are either too small or too far away to be significant. A pollution rose[3] for station 1 during the high SO_2 concentration period indicates the steam plant is the main emission source. Colbert Steam Plant is the only significant source in the direction indicated by the pollution rose (figure 2).

DISPERSION MODELING

The moderate wind speeds at stack height, and the fact that the wind had to cross the powerhouse before reaching the stacks, suggest that a building-induced aerodynamic effect could have caused the high monitored concentrations. Consequently, the screening techniques of Briggs[4] were used to assess and quantify the severity of the aerodynamic effects. Results of these calculations indicate that the plume was within the region of the building influence, but would not have been entrained within the building cavity zone. Therefore, the primary effect of the building influence would be (1) a reduction in plume rise due to increased entrainment immediately downwind of the stack and (2) enhanced vertical mixing (i.e., an increase in σ_z) below the plume due to building induced mechanical mixing. These assumptions are confirmed by the modeling results.

Modeling Assumptions

Based on the Brigg's calculations it was concluded that an elevated point source model would apply. Consequently, the excess was modeled using the centerline Gaussian diffusion model[5]; the centerline

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3. A pollution rose is a graphical display of the frequency that various combinations of wind direction and pollutant levels occur.

4. Briggs, G. A., "Diffusion Estimation for Small Emissions." Air Resources Atmospheric Turbulence and Diffusion Laboratory, May 1973 (Draft Report).

5. Equation 3.3

   "Workbook of Atmospheric Dispersion Estimates," D. Bruce Turner, Environmental Protection Agency, 1974.

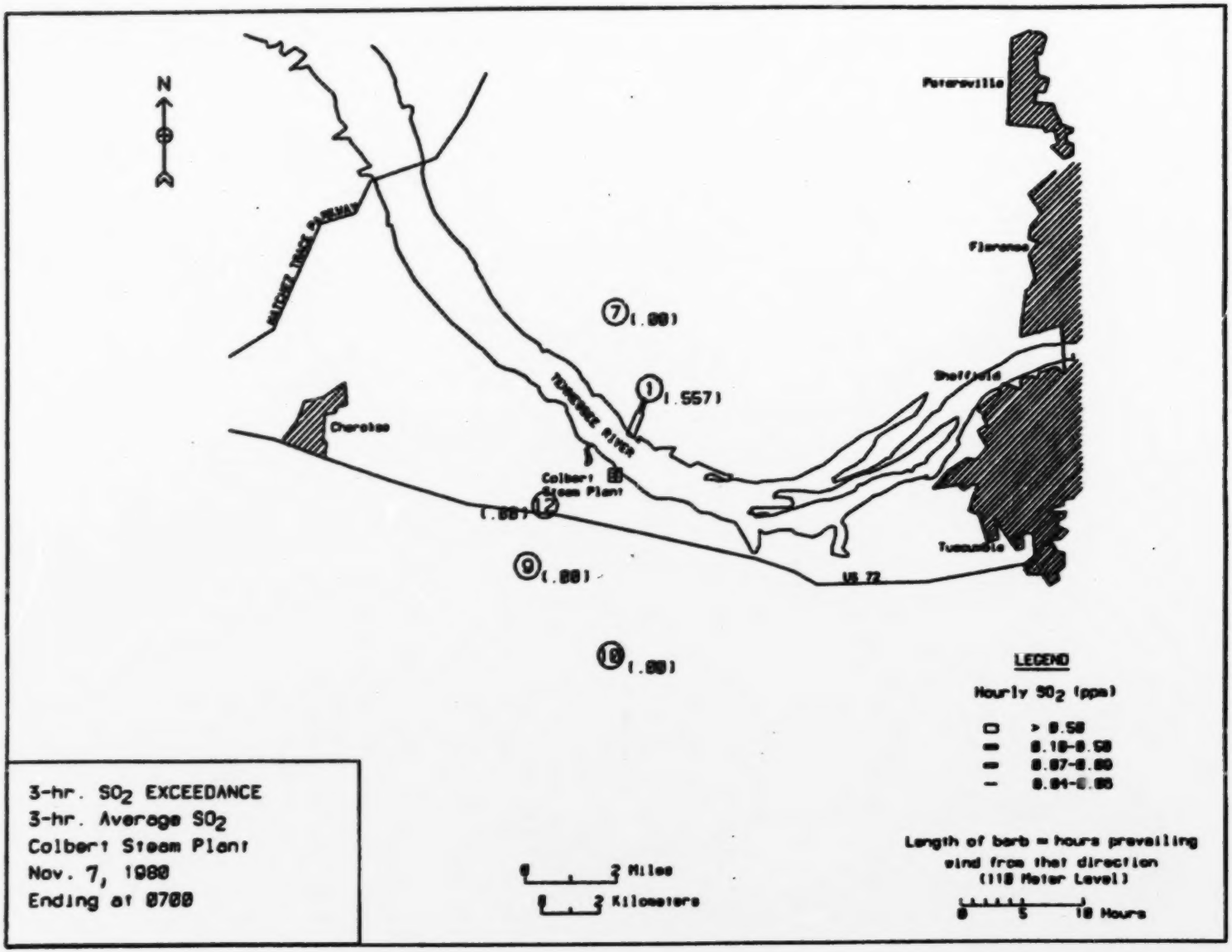

Figure 2. POLLUTION ROSE MAP

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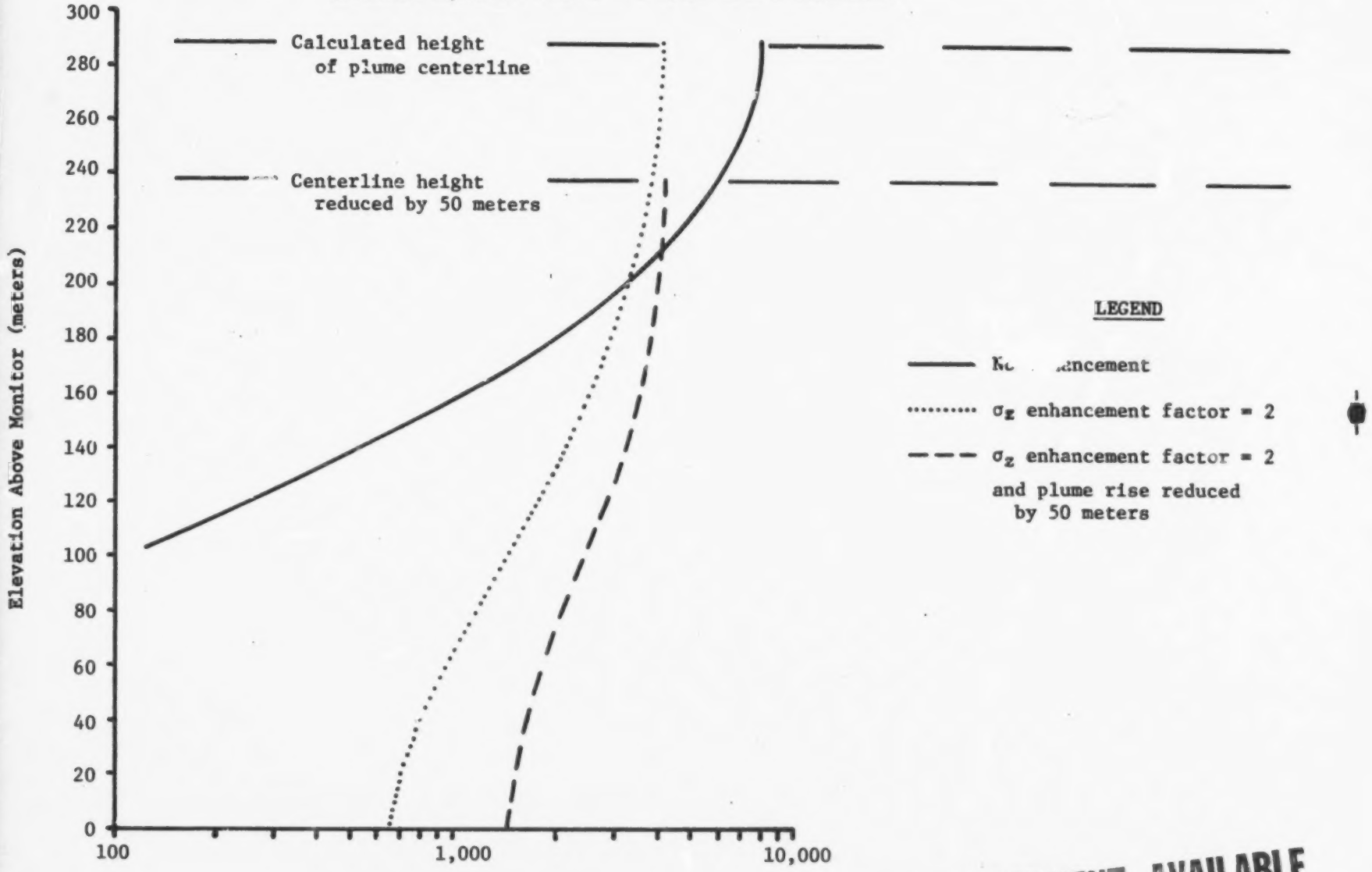
model is appropriate since the plume trajectory, based on the direction of the 110-m winds, would have been within two degrees of the affected monitor. Dispersion coefficients (sigmas) used in the model were based on an assumed class D stability in the plume layer. Use of class E stability indicated by tower temperature gradient measurements was judged to be inappropriate because of the moderate wind speeds at stack height (5 to 7 m/s) and because class E stability would not be consistent with building induced mechanical mixing. The assumed wind speed used in the model was 6 m/s; this is approximately the mean 110-m wind speed measured during the period of the excess.

Modeling Results

Simulated vertical concentration profiles for a location 2.9 km downwind of the steam plant are shown in figure 3. Several simulated profiles are shown in order to illustrate the range of uncertainty. The predicted ground-level concentrations range from less than 1 mg/m^3 for the case of no plume rise reduction and no σ_z enhancement to about 1450 $\mu g/m^3$ for a 50-m plume rise reduction and a σ_z enhancement factor of 2. The latter result is consistent with observed hourly average concentrations, which ranged from about 800 to 1950 $\mu g/m^3$ during the excess. Based on these results, it is concluded that the excess could not have occurred without some reduction in plume rise or enhancement of σ_z due to building influence. The use of the centerline equation and the several assumptions appropriately simulate the observed conditions for this case.

It should be noted that had the proposed new 183-m stack been used, it is likely that the excess would not have occurred. Preliminary calculations based on the new stack characteristics indicate that a plume from the new stack would have risen well above the region of the building influence and, consequently, would not have been affected by the perturbed flow at lower levels.

Figure 3. VERTICAL CONCENTRATION PROFILES AT 2.9 KILOMETERS BASED ON THE CENTERLINE GAUSSIAN EQUATION WITH $\bar{U}$ = 6 M/SEC AND D STABILITY



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POSSIBILITY OF RECURRENCE

Colbert Steam Plant was in compliance with applicable SO_2 emission standards, so an excess of the 3-hour standard was not expected. It is important to determine if a recurrence is likely because of actions TVA might have to take to prevent future excesses.

PLANT OPERATIONS

All four small units (units 1-4) were operating simultaneously during the excess while unit 5 was off-line. Had any one of the units been off-line, SO_2 emissions (and subsequent ground-level concentrations) would have been lowered by approximately 25 percent to a non-excess level. However, it is not unusual for all these units to be operating at the same time. During the 12 months preceeding the excess, all four units were operating simultaneously during 213 of 366 days.

WEATHER CONDITIONS

The two latest complete years (1978-1979) of meteorological tower data from Colbert Steam Plant were examined to determine how often conditions similar to those observed during the excess have occurred. During this period, similar wind conditions (wind direction 200-210°, wind speed 5-10 m/sec, and wind direction persistance 90-100 percent; all lasting longer than 2 hours) were observed 16 times. However, these conditions were combined with similar stability (stability class E) only five times. Therefore, near identical weather conditions can be expected approximately two or three times per year.

PROBABILITY OF EXCESSES

Colbert Steam Plant currently operates all four small units approximately 50-60 percent of the time, and unfavorable weather conditions (similar to November 7, 1980) can be expected two to three times per year; therefore, it is likely that one excess per year of the 3-hour SO_2 standard might occur under circumstances similar to those of November 7, 1980.

PREVENTION OF FUTURE EXCESSES

TVA recognizes the probability of SO_2 excesses under the current power plant configuration and operational circumstances, and is constructing a 183-m stack to replace the current 91-m stacks. Had this stack been in operation on November 7, 1980, the physical SO_2 emission point would have been twice as high above the surface and the effective plume height would have been approximately 360 m above monitoring station 1. This would have placed the plume above the terrain/ structure effects on the wind flow and probably prevented the excess.

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CONCLUSIONS

1. Colbert Steam Plant was the principal contributor to the 3-hour SO_2 excess measured at station 1 on November 7, 1980.

2. There were no unusual plant operational conditions or unexpected weather conditions related to this excess, although similar weather conditions occur infrequently at Colbert Steam Plant (two or three occasions per year).

3. Colbert Steam Plant was in compliance with the 4.0 $lb/10^6$ Btu SO_2 emission standard at the time the excess occurred.

4. The planned 183-m stack projected for completion by April 1983 would have been tall enough to prevent the 3-hour SO_2 excess.

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APPENDIXES

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APPENDIX A

Ambient SO_2 Data

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Table A-1

AIR MONITORING NETWORK

COLBERT STEAM PLANT

November 7, 1980

Monitor Number	From Colbert Steam Plant		Pollutants Measured[a]	Elevation Above Plant Grade[b] (m)
	Azimuth (°)	Distance (km)		
1	23	2.9	SO_2	15
7	360	5.5	SO_2, TSP	23
9	226	4.2	SO_2, TSP	14
10	180	6.0	SO_2	18
12	247	2.6	SO_2, TSP	2

a. SO_2 = Sulfur Dioxide
TSP = Total Suspended Particulate

b. Assumes intake at 4 m above ground.

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Table A-2

COLBERT STEAM PLANT

OBSERVED SO_2 CONCENTRATIONS

November 7, 1980

Hour Ending (CST)	Sulfur Dioxide Concentrations (ppm)									
	Station 1		Station 7		Station 9		Station 10		Station 12	
	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.
0100	0.050	0.020	0.030	0.020						
0200	.100	.060								
0300	.070	.010	.010							
0400	.340	.130	.010							
0500	.680	.310								
0600	.910	.750								
0700	.900	.610	.010							
0800	.660	.310	.010	.010						
0900	.020		.010	.010						
1000			.010	.010						
1100			.010	.010						
1200			.010							
1300			.010							
1400			.010							
1500			.010						.010	
1600			.010						.010	
1700									.010	.010
1800	.230	.070							.010	.010
1900	.320	.130							.010	.010
2000	.230	.060					.010		.010	
2100										
2200										
2300										
2400										
Max. 3-hr Average		.557		.010		.000		.000		.010
24-hr Average		.103		.003		.000		.000		.001

Note = Blanks are 0.000 ppm

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APPENDIX B

Meteorological Data

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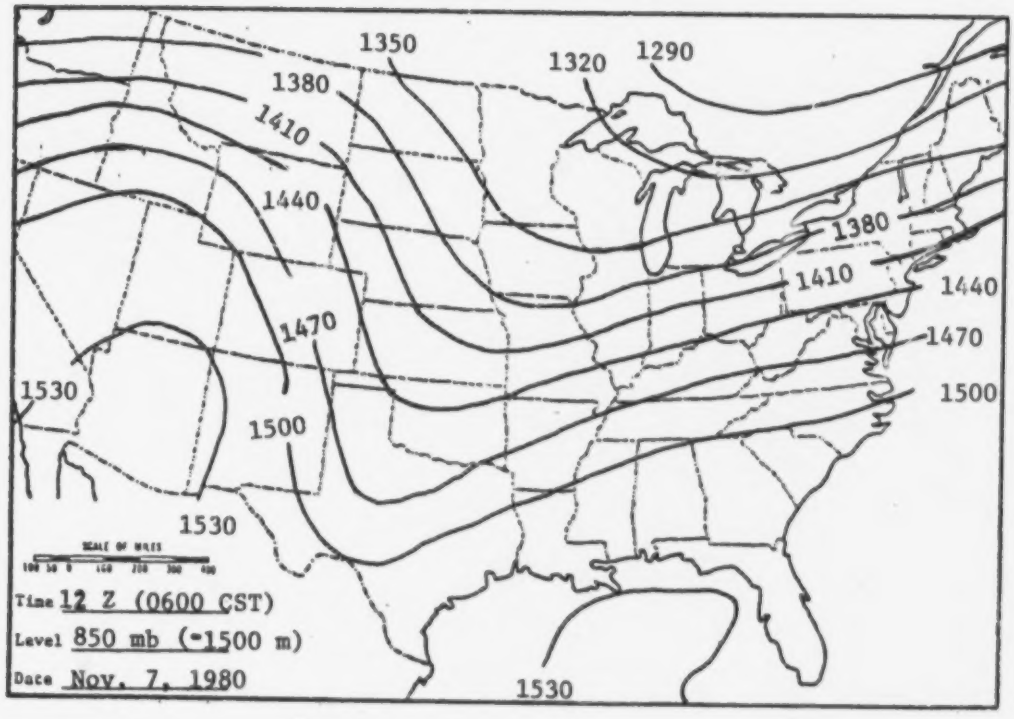

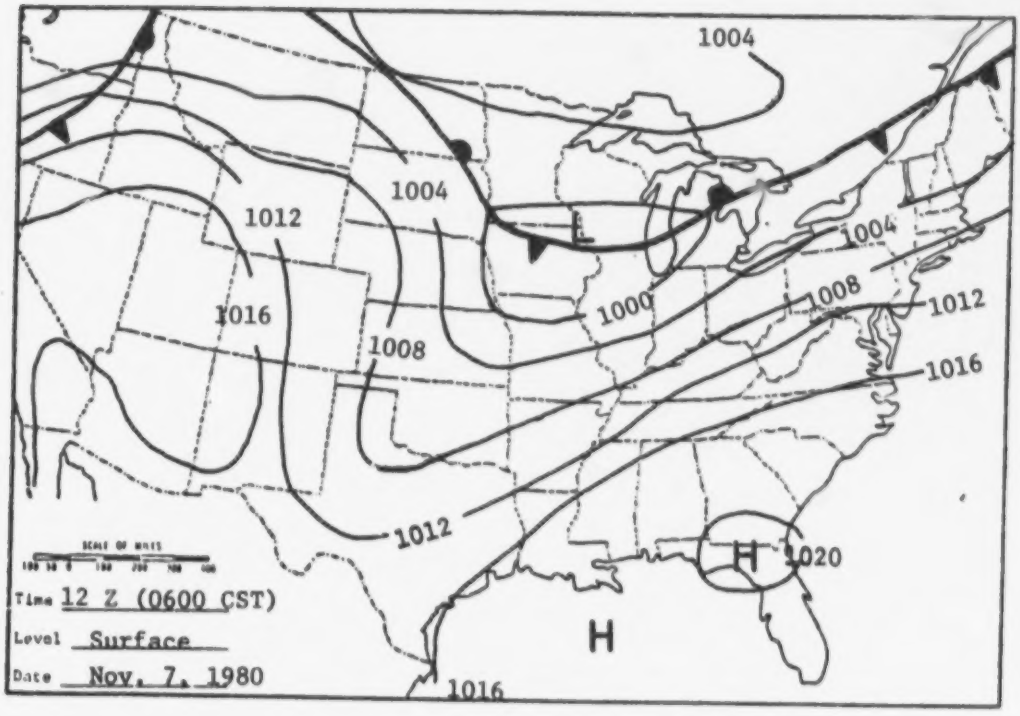

Figure B-1. SYNOPTIC WEATHER CHARTS - NOVEMBER 7, 1980

Figure B-2. TEMPERATURE PROFILES - NOVEMBER 7, 1980

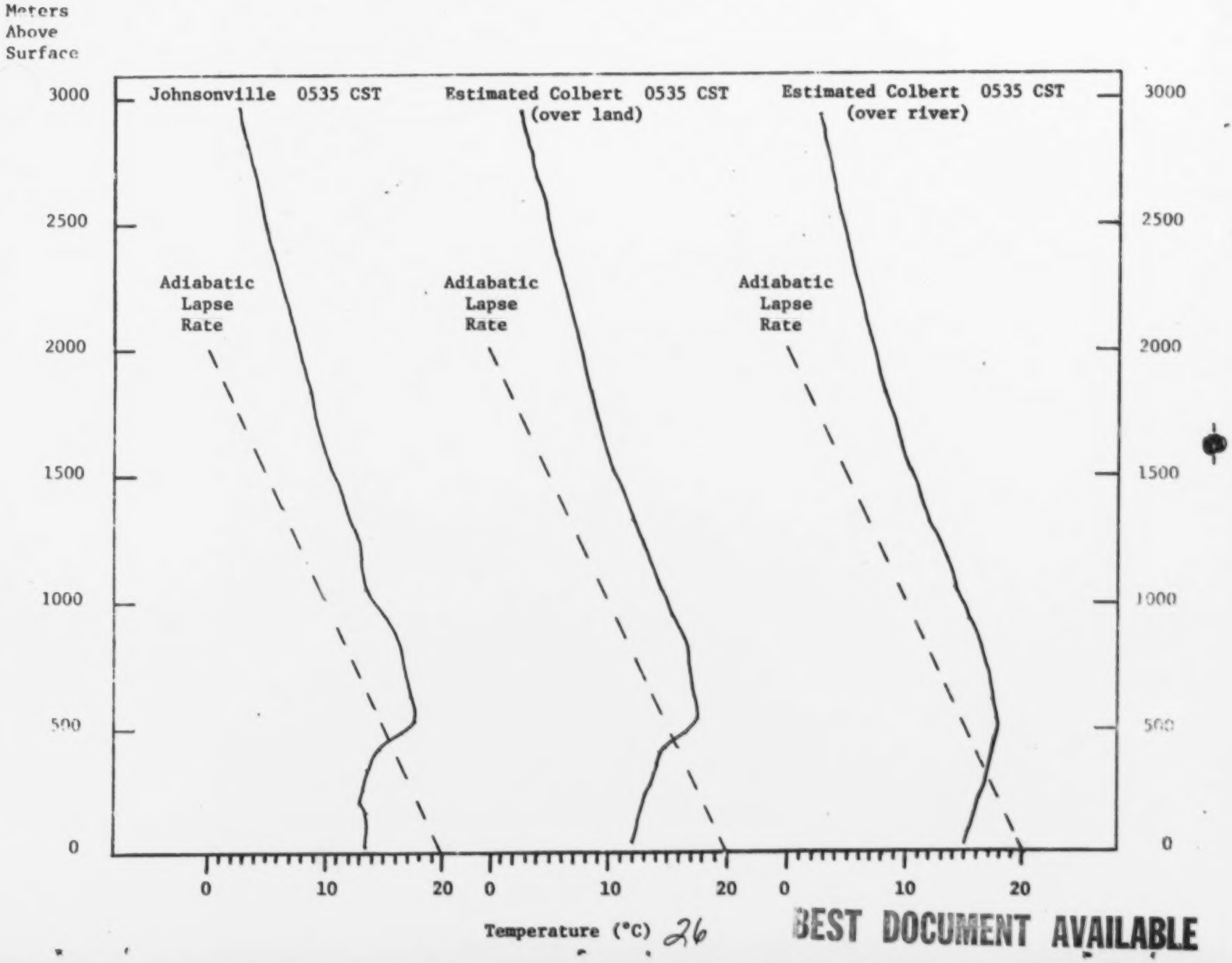

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Table B-1

COLBERT STEAM PLANT

Meteorological Tower Data

November 7, 1980

Hour Ending (CST)	110-Meter Winds			10-Meter Winds			Air Temperatures			Solar Radiation
	Wind Speed (m/s)	Wind Direction (°)	Persistence (%)	Wind Speed (m/s)	Wind Direction (°)	Persistence (%)	110-Meter (°C)	10-Meter (°C)	1-Meter (°C)	(LY/MIN)
100	7.7	201	97	1.8	183	48	13.9	13.1	12.8	0.00
200	8.9	200	100	2.2	198	52	13.5	12.7	12.4	.00
300	9.2	202	100	2.5	202	51	13.3	12.7	11.9	.00
400	9.2	203	100	2.8	197	50	13.2	12.2	12.0	.00
500	7.3	205	95	1.8	193	43	13.1	12.0	11.8	.00
600	6.0	202	98	1.7	180	50	12.7	11.9	11.6	.00
700	5.2	202	91	1.2	173	45	12.2	11.7	11.3	.02
800	4.7	207	71	1.2	181	29	13.2	13.6	13.5	.20
900	6.3	216	71	2.9	220	41	15.0	16.5	16.7	.49
000	6.3	222	74	3.4	217	42	17.3	19.1	19.4	.70
100	6.7	223	75	3.6	217	39	19.4	21.3	21.8	.86
200	7.9	231	72	3.9	226	38	21.1	22.8	23.2	.80
300	9.4	229	72	4.5	225	40	21.9	23.6	24.0	.80
400	10.8	226	71	5.1	223	36	22.7	24.2	24.6	.74
500	11.4	229	74	5.3	225	42	22.9	24.2	24.4	.55
600	10.5	221	90	4.6	212	44	23.0	23.7	23.7	.29
700	8.5	215	92	3.1	210	48	22.5	22.4	22.2	.05
800	7.2	212	84	1.7	198	47	21.4	20.4	19.9	.00
900	6.0	214	75	1.2	189	51	20.4	19.2	17.6	.00
000	8.0	222	83	2.1	209	37	19.8	18.8	17.9	.00
100	9.4	221	91	3.1	218	43	19.4	19.3	19.2	.00
200	6.7	222	87	1.9	210	45	18.8	18.4	18.1	.00
300	8.4	221	94	2.6	211	55	18.1	17.6	17.3	.00
400	11.2	218	97	3.7	213	48	17.8	17.4	17.3	.00

Table B-2

JOHNSONVILLE STEAM PLANT

Temperature Profile

November 6-7, 1980

Type: Aircraft Time: 2125 CST		Type: Aircraft Time: 0535 CST	
Height (m-AGL)	Temperature (°C)	Height (m-AGL)	Temperature (°C)
110	16.1	110	15.0
183	16.0	183	14.3
244	16.5	244	14.6
305	17.3	305	14.9
366	17.2	366	15.0
427	17.0	427	16.0
488	16.7	488	17.8
549	16.3	549	19.0
640	15.9	640	18.7
762	14.7	762	17.8
914	13.5	914	16.7
1067	12.7	1067	15.6
1219	12.7	1219	14.3
1372	12.0	1372	13.1
1524	11.3	1524	11.8
1676	10.9	1676	10.9
1829	10.6	1829	9.8

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Table B-3

JOHNSONVILLE STEAM PLANT

Wind Profile

November 7, 1980

Type: Pibal Time: 0020 CST			Type: Pibal Time: 0405 CST			Type: Pibal Time: 0804 CST		
Height (m-AGL)	Wind Direction (°)	Wind Speed (m/s)	Height (m-AGL)	Wind Direction (°)	Wind Speed (m/s)	Height (m-AGL)	Wind Direction (°)	Wind Speed (m/s)
76	193	7.1	76	188	4.2	76	202	6.0
222	210	11.9	222	220	8.8	222	222	9.6
362	229	17.1	362	243	17.2	362	247	14.1
502	232	17.4	502	245	20.2	502	255	21.6
637	237	17.6	637	251	26.1			
765	246	16.2						
893	251	16.2						

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APPENDIX C

SO_2 Emission Data

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Table C-1

HOURLY GENERATION AND SO_2 EMISSIONS[a]
COLBERT STEAM PLANT

November 7, 1980

Time Hour Ending	Gross Generation (MW)	SO_2 Emissions[b] (g/sec)
0400	792	3671
0500	776	3603
0600	776	3603
0700	777	3607
0800	787	3645
0900	781	3615
1000	793	3675
Average	783	3631

a. From TVA Power Projects Staff; Chattanooga, Tennessee; Dec. 18, 1980.

b. Based on following daily bunker analysis

Sulfur	2.4%
Heating Value	11,640 Btu/lb
SO_2 Emissions	3.9 $lb/10^6$ Btu

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APPENDIX D

Calculations

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Table D-1

PLUME RISE
COLBERT STEAM PLANT

November 7, 1980

Stack diameter (d) = 5.0 m

Stack gas exit velocity (v_s) = 16.0 m/sec

Stack gas exit temperature (T_s) = 436°K

Ambient air temperature (T) = 286°K

Average wind speed at stack top (u) = 6 m/s

Stack height (H) = 91 m

Stability class = D

Initial Plume Rise[a]

$$V_f = 0.785\ V_s\ d^2 = 314\ m^3/sec$$

$$F = 3.12\ V_f \left(\frac{T_s - T}{T_s}\right) = 337\ m^4/sec^3$$

$$x = 34\ F^{2/5} = 349\ m$$

$$\Delta h = \frac{1.6\ F^{1/3}\ (3.5\ x)^{2/3}}{6} = 212\ m$$

Final Plume Height

Plume height above stack base = H + Δh = 303 m[b]

Effective plume height above monitor = (plume height above stack base) - (monitor height above plant grade) = 303 - 15 = 288 m

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a. Based on Briggs Plume Rise Equations, "Dispersion Estimate Suggestion No. 2," Air Pollution Training Institute, Model Application Branch, Environmental Protection Agency, May 1, 1973.

b. Effective plume heights based on Briggs stable plume rise equation (with $d\theta/dz$ = 1.0 to 1-2 °C/100 m) ranged from 240 to 250 m.

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Table D-2

COLBERT STEAM PLANT ESTIMATES OF GROUND-LEVEL CONCENTRATIONS AT MONITOR 1

$$\chi = \frac{Q}{\pi \sigma_z \sigma_z u} \exp \left[\frac{1}{-2} \left(\frac{H}{\sigma_z} \right)^2 \right]^a$$

Parameter Values and Assumptions

Stability Class = D

$Q = 3600$ g/s
$u = 6.0$ m/s
$H = 288$ m
$\sigma_y = 182$ m
$\sigma_z = 64$ m

Enhancement Assumptions

(1) Enhanced σ_z; $\sigma_z = 2\,\sigma_z = 128$ m

(2) Reduced plume rise; $H = H - 50 = 238$ m

Results

Enhancement Assumption	$\frac{Q}{\pi \sigma_y \sigma_z u}$ ($\mu g/m^3$)	$\exp \left[\frac{1}{-2} \left(\frac{H}{\sigma_z} \right)^2 \right]$	χ ($\mu g/m^3$)	χ (ppm)
None	16,396	.00004	~1	0.000
1	8,198	.07956	652	.251
1 and 2	8,198	.17753	1455	.560

a. Equation 3.3

"Workbook of Atmospheric Dispersion Estimates," D. Bruce Turner, Environmental Protection Agency, 1974.

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